

Enabling the utilization of SAF blends up to 100%

At the first online seminar of AMF Task 66, four speakers presented their research activities and approaches for enabling the use of 100% SAF. First, **Markus Lehner (TU Leoben)** provided an overview on the development and optimization of alternative process routes to SAF with alcohol as feedstock. Subsequently, **Gurhan Andac (GE Aerospace, ASTM D02.06 Chair)** elaborated on fuel qualification/standardization. Next, **Georg Eckel (DLR)** presented results from collaborative flight measurement campaigns, focusing on climate benefits of SAF. Lastly, **Astrid Sonneveld (Neste)** provided a SAF producer perspective and talked about research activities regarding 100% SAF.

Terminology

SAF stands for sustainable aviation fuels, which are hydrocarbons derived from sustainable (non-fossil) feedstocks and processes. However, the term SAF is often used in an unspecific way, referring e.g. to:

- Synthetic aviation turbine fuel (SATF), which is an aviation turbine fuel containing synthesized hydrocarbons (used in the context of ASTM)
- Synthetic blending components (SBC) meeting the requirements of ASTM D7566 annexes
- Drop-in fully synthetic SAF – a synthetic kerosene, which chemically and functionally duplicates fossil Jet A/A-1 and is compatible with fleet and infrastructure
- Non-drop-in SAF – a synthetic kerosene which fulfills the requirements of jet engines while not being a chemical duplicate of Jet A/A-1 (new standard and certifications needed)
- SPK – synthetic paraffinic kerosene; SKA – synthetic kerosene with aromatics; and SAK – synthetic aromatic kerosene (aromatics).

The discussion would benefit from a more precise language that differentiates between these fuels.

Composition of SAF

The ideal carbon length for jet fuel is C8 to C16. Typical Jet A/A1 fuel is composed of around 32% cycloalkanes, 30% iso-alkanes, 20% n-alkanes and 18% aromatics. The current requirements in ASTM D7566 are based on fossil jet fuel specifications and e.g. set a minimum share of 8% aromatic compounds. The fuel properties depend on the molecular structure and thus can be tailored to optimize performance and operability (e.g. aromatics or cycloalkanes impact energy density). When aiming to

fully substitute fossil kerosene, there are two options: either to produce a chemically duplicated SAF that meets the current standardization limits and thresholds; or to produce a functional, but not chemically duplicated SAF that could have different specifications of fuel properties while providing the same functionality. However, defining new fuel specifications requires an excellent understanding of the functional requirements of aviation turbine fuels, fuel properties and interactions of fuel components.

Qualification of 100% SAF

ASTM is a standardization body, which certifies equipment for a specified fuel, with a focus on safety. SAF production pathways are approved by aviation OEMs, mainly airframe and engine manufacturers, who participate in ASTM working groups. Blended SATF (mixture of approved SBCs and fossil jet fuel, up to a certain percentage) once approved can be used in all existing commercial aircraft. The ASTM D02.06 Task Force focuses on 100% SATF and various OEMs have already committed to deliver equipment certified for the use of 100% SATF by 2030. Requirements for 100% SATF are emerging and are more stringent than the ones in place for Jet A/A-1, even though successful test flights have already been executed. But safety must be guaranteed on a continuous basis over many years, so OEMs are reluctant to lower the requirements. To achieve a fully formulated jet fuel and meet the requirements, 100% SATF could be a blend of paraffinic (SPK) and aromatic (SAK) components. So far, no aromatic only blending components have been certified.

Strategies & Considerations

The alcohol-to-jet (ATJ) pathway produces only a small amount of aromatics, due to the moderate temperatures in the oligomerization step (<350°C). One strategy towards achieving a 100% functional substitute is to increase the share of aromatics by the implementation of an aromatization step. Another strategy is to lower the minimum share of aromatics in the ASTM D7566 requirements. Aromatics are responsible for non-CO₂ effects, such as soot formation. Thus, reducing the minimum share would be environmentally beneficial. However, in current aircraft design aromatics are required for seal swelling, and they also impact other fuel properties. There is a tradeoff between fitting the fuel to the aircraft and fitting the aircraft to the fuel.

Some SAF producers work together with OEMs to define fuel requirements, stating that changes in future aircraft and thus the option of adaptations in fuel properties would

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improve availability and affordability of SAF. The price gap between fossil Jet A/A1 and SAF is already one of the main barriers of SAF implementation. Producing SAF with the currently proposed fuel properties for 100% SAF utilization is an economic challenge, making production of SAF even more expensive. Since no market currently requires 100% SAF, airlines are not willing to pay more for it.

Key messages

- The term SAF can be misleading, but in most cases refers to synthetic blending components. These SBC can't be used as jet fuel on their own but must be blended with Jet A/A-1.
- Current requirements for ASTM D7566 set a minimum share of aromatics, based on fossil jet fuel specifications. Aromatics are required for e.g. seal swelling in current aircraft design and impact other properties, but they are also responsible for non-CO₂ effects. There is a tradeoff between adapting aircraft designs and adapting fuel properties.
- First flight measurement campaigns with 100% SAF were successful and showed that aromatic-free SAF significantly reduces non-CO₂ effects such as soot, particle matter, and ice crystal formation.
- The market is not yet ready for 100% SAF and airlines are not willing to pay more for such a fully compatible fuel, which makes production economics challenging.

Research gaps

- Better understanding of functional requirements on aviation turbine fuels and interactions between different fuel properties to identify opportunities to lower the standardization requirements for (100%) SAF utilization in new aircraft designs. E.g. aromatics have an impact on various properties, such as the cetane number. These interactions must be understood to define minimum standardization requirements and to approve paraffinic SAF.
- Required changes in aircraft design to fit (100%) SAF utilization in case of adapted standardization requirements.
- Environmental and climate benefits of utilizing (100%) SAF. Especially the contribution of non-CO₂ effects on the climate impact of aviation (e.g. different particle types responsible for forming ice crystals) must be assessed.
- Development and upscaling of new SAF production pathways and diversification of sustainable feedstock to allow for 100% non-drop in SAF.
- Research on the consequences of multi-blending different SBCs and resulting fuel properties.